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NOTES ON THE SCALY SPECIES OF HYDNACEAE

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(WITH PLATE 20)

Students of our Hydnaceae have frequently emphasized the need of more complete field notes upon our American species. Banker, in his revision of the North American Hydnaceae, speaks repeatedly of the lack of definite field notes in regard to our species and the resultant uncertainty in regard to the status of some of them.

As a rule our species are quite rare, Banker for example having been able in six years careful watching to find but two specimens of *Sarcodon imbricatus*. In my collecting grounds at Asheville, North Carolina, on the contrary, they occur at times in abundance, giving ample opportunity for study. Some of my observations made there upon the scaly species of Hydnaceae seem to explain some of the difficulties with this group and for that reason to merit publication.

The most abundant Asheville species is the one commonly referred to *Sarcodon imbricatus* (L.) Karst., though considered by some rather *Sarcodon subsquamosus*. This was regularly found in August and early September, and aside from the growth changes mentioned below, was quite constant. Its appearance is well shown in Fig. 1. The fleshy pileus was light-grayish-brown to dark-brown, with conspicuous, superficial, floccose scales which were larger and more prominent at the center. Along with this typical form were found also other forms which from the circumstances of their growth were taken for older forms of the same

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species. These were, however, so different in their appearance that Lloyd, who saw photographs and specimens, did not think it possible that they could belong to the same species. It became evident that it would be of value to determine the growth changes of the species in order to fix the status of these aberrant forms.

The following season a group of three plants was selected for study. They were in the woods very close to my laboratory so that they could be marked and visited at frequent intervals. The three plants were typical, and with a slight difference in the length of the stipe were practically alike.

One of these plants was collected and photographed with the result shown in Fig. 1. The other two were left undisturbed and visited at intervals of two or three days throughout their growing season. The period of growth proved longer than had been anticipated, being about three weeks before the cycle of growth was completed. During this time the remaining plants changed so as to be almost unrecognizable. The scales soon disappeared. This had been anticipated, as they are clearly superficial, and can easily be removed without serious injury to the surface of the cap. Ten days removed the last traces of the scales in the two plants observed, though it developed later that in rainy weather they are lost more quickly. Along with this change a second change was taking place in the teeth. In the young plant these were from one to ten mm. long, exactly as Banker describes them. With age they became much longer and coarser, reaching, at the end, a length of 25 mm., giving the plants a very shaggy appearance. A third change was entirely unexpected. It will be noted from a careful examination of Fig. 1 that the appearance of the cap indicates a somewhat looser structure at the center. This became very marked with age. The loose tissue soon began to disappear, forming a hollow at the center which gradually extended to the base of the stipe, giving the plant an infundibuliform appearance. These changes brought the two plants into absolute agreement with the aberrant forms collected before and established them as simply old forms of *Sarcodon imbricatus*. Fig. 2 will make these changes clear and indicate the marked difference in their appearance.

These facts seem to explain some of our difficulties in regard to this species. It becomes clear that our descriptions should be extended to make it clear that the scales of this species, which have been taken as diagnostic, are only a phase of the young plant, and that entirely smooth, infundibuliform specimens with unusually long teeth are to be expected. It also becomes apparent that much of our so-called *Sarcodon laevigatus,* differing from *Sarcodon imbricatus* in its smooth pileus, may well be *Sarcodon imbricatus* in which rain or age has removed the scales. Banker in his discussion of the specimens of *Sarcodon laevigatus* which he had examined says, "The plants of the quoted collections vary greatly among themselves. They agree in being large, short-stemmed, with broad pilei, coarse teeth, and brown color. A puzzling fact in connection with them is that the collectors themselves refer their specimens frequently to *Sarcodon subsquamosus* or even to *Sarcodon imbricatus* indicating that, at least in the fresh state, the pileus shows some indications of scales, but there are no signs of scales in the dried specimens." One specimen of my own collection in the set discussed seems certainly in the light of later observations to be *Sarcodon imbricatus,* and the clear statement in regard to them would seem to create a strong suspicion that this is true of the remainder.

The other scaly species which was abundant at Asheville was *Sarcodon fennicus,* as Banker and Lloyd understand that species. One European authority to whom specimens and photos were submitted considered it rather *Sarcodon fuligineo-violaceus* (Kalch.) Quél. which name was used in the treatment of the Hydnaceae of North Carolina. As will be indicated below, I have since found an entirely different plant farther south which seems clearly this species indicating that the North Carolina plant should be considered *Sarcodon fennicus.* In maturity this species is well marked. The scales are not superficial and floccose, but are formed by the surface of the pileus breaking into small triangles, whose points become somewhat reflexed, as will be seen from Fig. 3. The teeth are very short and crowded, and the base of the stipe has a peculiar greenish-blue stain, and the plant has a strong, rather unpleasant odor and bitter taste.

The growth changes of this species are in a way the reverse of the other scaly species. The young plant is entirely smooth, the scales being a later phase. Also the greenish color of the stipe is either entirely lacking or inconspicuous at first.

These young forms answer in every way to the requirements of *Sarcodon Underwoodii* Banker, which seems on this account to need further study and field observation to fix its status.

It remains only to speak of *Sarcodon fuligineo-violaceus*. During the winter of 1920 a plant was observed several times at New Smyrna, Florida, which seems clearly this species, as Lloyd and Banker understand it. The specimens found were smaller than its relative *Sarcodon fennicus,* with a shorter and thicker stipe. The pileus was brown with a faint violaceous tint, while the short crowded teeth in the young plant were beautifully violaceous. The pileus was somewhat pubescent, but smooth or with a few slight innate scales. It is very distinct and when seen growing would at once be distinguished from its relative. This seems to be Kalchbrenner's species and will be easily recognized from the figure.

PERRY, OHIO.

EXPLANATION OF PLATE 20

Fig. 1. *Sarcodon imbricatus* (L.) Karst.
Fig. 2. *Sarcodon imbricatus,* older form showing hollow stipe and smooth pileus.
Fig. 3. *Sarcodon fennicus* Karst.
Fig. 4. *Sarcodon fuligineo-violaceus* (Kalch.) Quél.

FACTORS INFLUENCING THE INFECTION OF WHEAT BY TILLETIA TRITICI AND TILLETIA LAEVIS [1]

JAMES A. FARIS

The relation of environmental factors to losses from wheat bunt has long been a matter of observation and experiment. With few exceptions, the experimental work has been carried out with field plantings where the groups of factors influencing infection could neither be isolated nor controlled. The limited number of controlled experiments dealing with the influence of environmental factors in the development of bunt have been largely upon *Tilletia Tritici* (Bjerk.) Wint. Very little is known concerning the temperature relations of *Tilletia laevis* Kühn, except what is inferred from temperature and rainfall records during field plantings. Not all authors have stated with which of these species of *Tilletia* they were working, and hence some of the results are of uncertain application.

There seems to be pretty general agreement that low soil temperatures are most favorable for infection by *Tilletia Tritici*. While Tubeuf (**19, 20**) believed that high temperatures promote bunt production, Volkart (**21**) concluded that lower soil temperatures favor the bunt. Hecke (**6**) found, with some exceptions, that early sowings of spring wheat gave higher percentages of bunt than late plantings. Munerati (**9**) obtained 92–100 per cent of bunt in wheat germinated at 7–8° C., while the same varieties gave 1.4–12 per cent when germinated at 18–20° C. In a more recent paper (**10**) he finds that seed germinated at 10–12° C. gave 13.2–39.3 per cent infection while the same two varieties gave 0–1.4 per cent bunt when germinated at 22–25° C. Heuser (**7**) secured 67.1–94.7 per cent bunt in three varieties germinated at 6–10° C. but only 1.8–6 when they were germinated at 16–22° C. Hungerford (**8**) secured higher infections in each of four moisture experiments at 9–12° C. than at 17–25° or 25–28°.

[1] Brooklyn Botanic Garden Contributions No. 41.

Since little is known of the temperature relations of *Tilletia laevis,* experiments were undertaken to germinate inoculated seed under controlled conditions in order to determine the influence of certain soil factors upon infection by this fungus. Similar experiments were carried out with *T. Tritici* in order to learn whether one or the other species was being more favored at any of the various moistures, temperatures, etc. If such proved to be the case it might suggest an explanation of why *T. Tritici* is more generally distributed throughout cooler regions than is *T. laevis.*

In view of the opinion held by many workers that the wheat which is slower in germination is more susceptible to infection by the bunt fungi, and of the recent results reported by Reed and Faris (**16**) which indicate that higher infection is not correlated with slow germination of different varieties in the smuts of oats and sorghum, a series of experiments was undertaken to determine whether or not the seeds within a variety which germinate slower are more heavily infected.

A further interesting problem was to determine whether there exists in either of these bunt fungi well defined biologic forms, such as I have recently shown to occur in the covered smut of barley (**4**) and as Reed (**13**) finds in the smuts of oats.

PART 1. SOIL FACTORS INFLUENCING INFECTION OF WHEAT BY BUNT FUNGI

A. RESULTS WITH WINTER WHEAT

Series I. The Influence of Temperature upon the Infection of Two Varieties of Winter Wheat by Tilletia Tritici and Tilletia laevis

In order to determine the influence of temperature upon the infection of winter wheat by *Tilletia Tritici* (Bjerk.) Wint. and *T. laevis* Kühn, two varieties of wheat were germinated in constant temperature tanks in the fall of 1923 and kept there until the seedlings had produced the second green leaf. They were then transplanted to the field where they were matured the following summer. The general methods of handling these temperature tank experiments were the same as those reported in a previous

paper (3). The seeds of the two wheat varieties, while apparently free from bunt, were treated with hot water as a precautionary measure. The two smut collections were made in July, 1923, the *Tilletia Tritici* coming from near Geneva, N. Y., and the *T. laevis* from the New York Agricultural Experiment Station at Ithaca, N. Y. The former occurred upon Dawson wheat, and the latter upon a variety known as Ontario Agricultural College No. 104. Therefore, these two varieties were chosen as hosts in the temperature experiments. I am obligated to Prof. H. H. Love of Cornell University for supplying seed of these varieties.

Plantings of both varieties inoculated with the spores of each smut were made in a potting soil testing pH 7 and having a moisture content of 61.9 per cent of its water holding capacity. Germination tests of the smut spores were made but the percentages were not determined because of the difficulty of culturing bunt spores in such a way that accurate counts could be made. The germination tests were made by sprinkling the spores upon moist earth in petri dishes and incubating them in the ice box. *Tilletia laevis* germinated very well but *T. Tritici* germinated rather feebly. The results of this series of experiments are given in Table I and summarized in the graphs of Fig. 1.

TABLE I

THE INFLUENCE OF TEMPERATURE UPON INFECTION OF DAWSON AND ONTARIO AGRICULTURAL COLLEGE NO. 104 WINTER WHEATS BY *Tilletia laevis* AND *Tilletia Tritici*

Variety	Temp.	*Tilletia Tritici*				*Tilletia laevis*			
		Total number plants	Number smutted	Number partially smutted	Per cent infected	Total number plants	Number smutted	Number partially smutted	Per cent infected
Dawson (Honor).	5° C.	45	2	4	13.3	53	17	20	69.8
	10° C.	51	1	6	13.7	65	17	25	64.6
	15° C.	67	0	4	5.9	65	23	12	53.8
	20° C.	51	0	0	—	58	3	6	15.5
	25° C.	59	0	0	—	48	0	0	—
	30° C.	56	0	0	—	56	0	1	1.7
O. A. C. No. 104.	5° C.	46	1	0	2.1	42	12	15	64.2
	10° C.	56	1	4	8.9	64	18	21	60.9
	15° C.	58	1	0	1.7	52	15	14	55.7
	20° C.	57	0	0	—	61	5	5	16.3
	25° C.	58	0	0	—	54	0	1	1.8
	30° C.	59	0	0	—	59	0	0	—

The Results with Tilletia laevis.—The infections were highest at the lowest temperature in both varieties when the seed had been inoculated with *T. laevis*. There was a slight falling off at 10° C., a further drop at 15° C., but the infection percentages were still very high. From 5° C. to 15° C. the temperatures are well within the range of high infection. At 20° C. we have a marked drop which continues at 25° C. until the zero point is reached in one

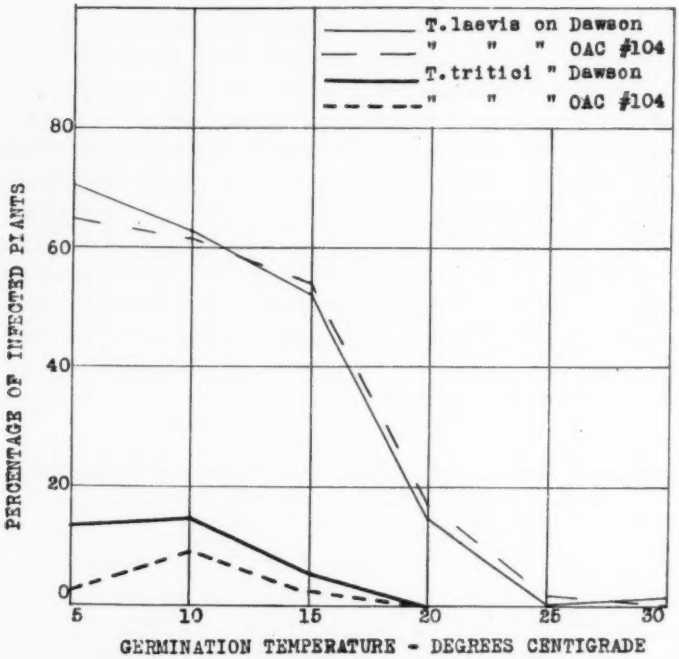

FIG. 1. Graph showing the influence of temperature upon infection of Dawson and O. A. C. No. 104 winter wheat by *Tilletia laevis* and *T. Tritici.*

variety and almost reached in the other. At 25° C. one plant of O. A. C. No. 104 was partially smutted and at 30° C. one plant of Dawson became partially infected.

The curves for the two varieties (Fig. 1) are remarkably close together throughout the entire temperature range, thus the infection results of each variety check those secured for the other.

Results with Tilletia Tritici.—The infections secured with *Tilletia Tritici* are far lower than could reasonably be expected and for this reason it seems that some other condition than temperature determined whether or not the disease developed. It should be noted, however, that such smut as occurred indicates that with these two varieties slightly more disease occurred at 10° C. than at 5° C. The infections are so low that no general conclusion should be drawn. No infections occurred at 20°, 25° or 30° with this species. I am at a loss to explain these low infections with *T. Tritici*, as the inoculum was collected and handled exactly the same as the *T. laevis*. It may be, however, that the low infections secured with this collection of smut were due to poor spore germination. It should be noted, however, that the smutted heads of *T. Tritici* collected in the field appeared to be less than half the height of the sound heads in the same field. The marked shortness of the diseased stalks observed in collecting this smut in the field was not apparent in the diseased plants in these experiments. In fact, the culms with smutted heads varied from a few inches to the full height of the sound plants.

Series II. The Influence of Soil Moisture and the Character of the Substrata upon Infection

In this series of experiments seed of the same two varieties of wheat used in series I were germinated in the temperature tanks, from which they were transplanted to the field upon the appearance of the second leaf. Two substrata were used—a potting soil and a pure quartz sand. In the soil experiments two moistures were used, *i.e.*, 30 and 61.9 per cent of the moisture holding capacity based upon the oven dry weight. Three moisture contents (10, 45, and 80 per cent) were used with the quartz sand. All seed were germinated in the temperature tanks at a temperature which varied somewhat, the first two days it was held at 14° C., then one day at 12° C. from which it was lowered to 10° C. until the seedlings were transplanted. All seeds were planted at the same time but those at the lowest moistures germinated so slowly that they were not transferred to the field until three days after the seedlings produced at the higher moistures. Smuts from the

same two collections of series I were used in these experiments. The results are recorded in Table II.

TABLE II

THE INFLUENCE OF THE SOIL MOISTURE AND THE CHARACTER OF THE SUBSTRATA DURING GERMINATION UPON INFECTION OF WINTER WHEAT BY *Tilletia Tritici* AND *Tilletia laevis*

Variety	Substrata	Per cent moisture	*Tilletia Tritici*				*Tilletia laevis*			
			Number plants	Number smutted	Number partially smutted	Per cent infected	Number plants	Number smutted	Number partially smutted	Per cent infected
Dawson.....	Quartz sand	10	49	0	0	—	41	11	7	43.9
		45	52	0	0	—	46	10	11	45.6
		80	54	1	1	3.7	47	13	16	61.7
Dawson.....	Potting soil	30	50	2	2	8.0	49	26	4	61.2
		61.9	47	1	0	2.1	52	30	15	86.5
O. A. C. No. 104...	Quartz sand	10	40	0	3	7.5	33	18	3	63.6
		45	46	1	0	2.2	42	18	14	76.2
		80	53	0	1	1.9	45	22	8	66.6
O. A. C. No. 104...	Potting soil	30	52	0	1	1.9	46	34	3	80.4
		61.9	51	0	2	3.9	52	32	4	69.2

Results with Tilletia laevis.—In both varieties the seed germinated in soil gave higher infection than did that germinated in quartz sand. The infections at all moistures in both soil and sand are sufficiently high to demonstrate that neither the soil moisture content nor the character of the substrata here used have very narrow limits of infection under the conditions of these experiments. It should be pointed out, however, that these seedlings were germinated in covered glass jars, and hence in an atmosphere of very high humidity. It would seem that just such conditions might prevail in this climate when wheat is planted.

Results with Tilletia Tritici.—Again the infections with this species were very low and no conclusions can be drawn from the results obtained.

Series III. The Influence of Date of Planting upon Infection

For this experiment two plantings were made, using the same two varieties of series I and II, as well as the same two species of

the fungus. The seed was inoculated with powdered spores and planted in the experiment field. The first planting was made October 9, and the second October 25, 1923. The results are recorded in Table III.

TABLE III

INFLUENCE OF DATE OF PLANTING IN THE FIELD UPON INFECTION OF TWO VARIETIES OF WINTER WHEAT BY *Tilletia laevis* AND *Tilletia Tritici*

Variety	Date planted	*Tilletia Tritici*				*Tilletia laevis*			
		Number plants	Number smutted	Number partially smutted	Per cent infected	Number plants	Number smutted	Number partially smutted	Per cent infected
Dawson	Oct. 9, 1923	77	1	5	7.8	49	31	2	67.3
Dawson	" 25, "	29	1	0	3.4	37	22	1	62.2
O. A. C. No. 104	Oct. 9, "	99	2	1	3.0	44	29	5	77.3
O. A. C. No. 104	" 25, "	26	0	0	—	31	22	3	80.6

Results with Tilletia laevis.—The plantings gave fairly high infection for field sowing on both dates. In one variety (Dawson) higher infection was secured in the planting of October 9, while in the other variety a higher percentage of the plants were diseased in the plantings of October 25. These variations are less than five per cent in either case and are as close as could be expected under the conditions of field planting. The soil temperatures ranged between 18° C. and 5° C. throughout the period from October 9 to November 5, but the temperatures were very much the same for the first seven days after each planting, being around 12° C. for the planting of October 9 and 10° C. for that of October 25.

B. RESULTS WITH SPRING SOWN WHEAT

A number of American investigators (**5**) have experienced difficulty in securing bunt infections in wheat seeded in the spring. However, Hecke (**6**) and Munerati (**9, 10**), working in Europe, report satisfactory bunt infections in wheat planted in the spring. In order to determine whether any marked differences occurred in results secured with winter wheat germinated under controlled

conditions and matured in the field and infections secured by germinating inoculated seed of both winter and spring wheat under controlled conditions in the spring and maturing them in the field, the following series of experiments were carried out.

Series IV. The Influence of Temperature upon the Infection of Dawson, Marquis, and Red Fife Wheat by Tilletia laevis and Tilletia Tritici

One variety of winter wheat (Dawson) and two spring wheat varieties (Marquis and Red Fife) were inoculated with the spores of two collections of each of the two species of bunt fungi. These

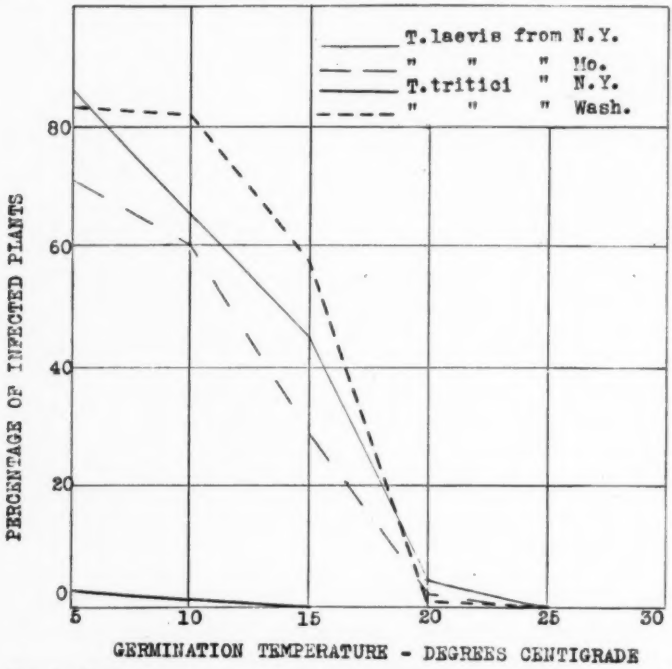

FIG. 2. Graph showing the influence of temperature upon the infection of Dawson winter wheat by *Tilletia laevis* and *T. Tritici*

three varieties, each inoculated with four smut collections, were germinated in a potting soil testing pH 7, with a moisture content

TABLE IV

THE INFLUENCE OF TEMPERATURE UPON THE INFECTION OF DAWSON, MARQUIS, AND RED FIFE WHEAT BY *Tilletia laevis* AND *Tilletia Tritici*

Variety	Germination temperature ° C.	*Tilletia Tritici*								*Tilletia laevis*							
		Smut from New York				Smut from Washington				Smut from New York				Smut from Missouri			
		Total plants	Number smutted	Number partially smutted	Per cent infected	Total plants	Number smutted	Number partially smutted	Per cent infected	Total plants	Number smutted	Number partially smutted	Per cent infected	Total plants	Number smutted	Number partially smutted	Per cent infected
Dawson.....	5	60	2	0	3.3	55	14	32	83.6	49	15	27	85.9	70	32	18	71.4
	10	68	0	1	1.5	61	33	17	81.9	63	28	13	65.1	63	27	11	60.3
	15	75	0	0	—	73	35	7	57.5	79	21	15	45.6	83	16	8	28.9
	20	78	0	0	—	78	1	0	1.3	80	2	2	5.0	84	2	0	2.4
	25	60	0	0	—	58	0	0	—	66	0	0	—	50	0	0	—
	30	61	0	0	—	45	0	0	—	45	0	0	—	52	0	0	—
Marquis.....	5	42	0	0	—	44	0	14	31.8	41	0	8	19.5	43	1	8	20.9
	10	71	0	2	2.8	53	8	9	32.1	56	3	20	41.1	68	55	3	85.3
	15	81	0	0	—	79	14	8	27.8	84	9	9	21.4	81	17	2	23.5
	20	74	0	0	—	73	2	0	2.8	72	1	0	1.4	70	2	0	2.9
	25	69	0	0	—	66	0	0	—	65	0	0	—	62	0	0	—
	30	68	0	0	—	66	0	0	—	65	0	0	—	65	0	0	—
Red Fife.....	5	40	0	1	2.5	40	0	18	45.0	45	3	25	62.2	37	12	8	54.1
	10	69	0	0	—	62	19	14	53.2	50	11	11	44.0	52	20	7	51.9
	15	73	0	0	—	75	10	5	20.0	70	10	9	27.1	66	27	1	42.4
	20	71	0	0	—	51	1	1	3.9	68	1	1	2.9	83	2	0	2.4
	25	64	0	0	—	77	0	0	—	55	0	0	—	73	0	0	—
	30	60	0	0	—	52	0	0	—	56	0	1	1.8	47	0	0	—

of 61.9 per cent, in constant temperature tanks at 5°, 10°, 15°, 20°, 25°, and 30° C. After the appearance of the second green leaf the seedlings were transplanted into paper pots, and kept in the greenhouse for a few days until favorable weather for plantings in the experiment field. The results secured are given in Table IV and summarized in the graphs of Figs. 2, 3, and 4.

Results with Dawson Wheat Planted in the Spring.—The infection percentages secured in these experiments with Dawson wheat

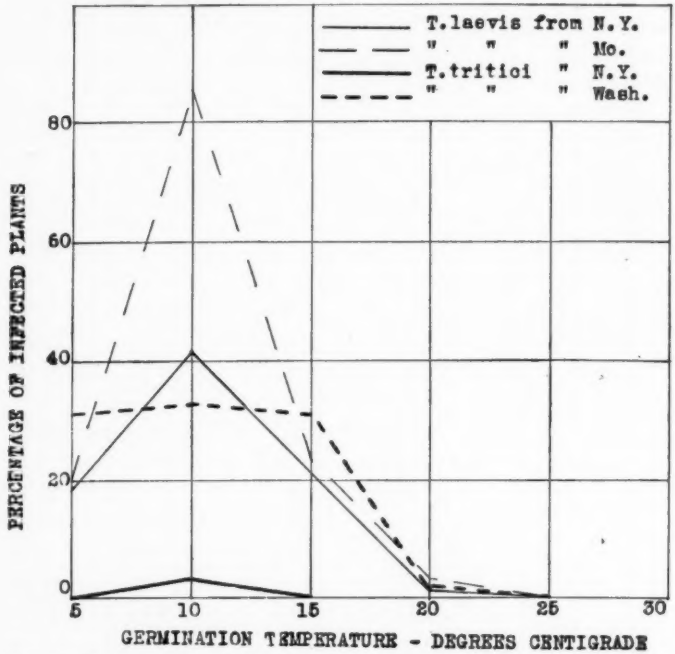

FIG. 3. Graph showing the influence of temperature upon the infection of Marquis wheat by *Tilletia laevis* and *T. Tritici*

inoculated with *T. laevis* from New York are remarkably close to those obtained in the fall planting with another selection of this variety inoculated and germinated under the same soil conditions. (Compare Tables I and IV.) At the two low temperatures, the infections are slightly higher in the spring than in the fall planting,

but are somewhat less at 15° and 20° C. The Missouri collection of *T. laevis* gave slightly lower percentages of infection at 5°, 10°, and 15° C. than did the New York collection. On the other hand, the infections with *T. Tritici* from Washington were higher at 10° and 15° than were those secured with either collection of *T. laevis*. The *T. Tritici* from New York again gave very few diseased plants.

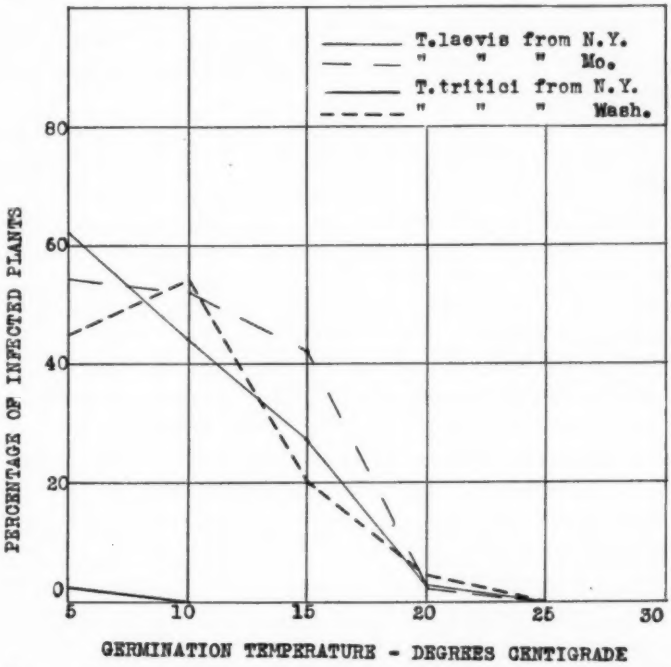

FIG. 4. Graph showing the influence of temperature upon the infection of Red Fife wheat by *Tilletia laevis* and *T. Tritici*

These experiments with winter wheat showed the same deleterious effects of high germination temperatures as I have recorded for Texas winter barley (3). The plants of Dawson from the 5° tank tillered well and matured at the same time as those of Marquis and Red Fife germinated with them at higher temperatures. At higher temperatures the winter variety produced tillers

profusely, but matured very few spikes. Such heads as were produced came a month later than did those of Dawson germinated in the 5° tank or the other spring varieties germinated at the higher temperatures.

Results with Marquis and Red Fife Wheats.—The striking feature of the results with Marquis wheat is that with every smut collection infections were higher at 10° C. than at 5° C. Very high infection was secured with the *T. laevis* from Missouri at 10°.

This marked increase at 10° is followed by a rapid decline in the percentages at 15° and 20° and in no case was there any infection at 25° or 30°.

Red Fife proved to be very susceptible at both low temperatures, the percentages dropping rapidly in all cases except with *Tilletia Tritici* from Washington where there was a small increase of infection at 10° C. followed by a very rapid drop at 15°, 20°, and 25°. One plant of this variety was partially smutted at 30° in the collection of *T. laevis* from New York. In the fall plantings (Table I) one plant was also partially smutted at a germination temperature of 30° C.

PART II. PHYSIOLOGICAL FACTORS INFLUENCING THE INFECTION OF WHEAT BY BUNT FUNGI

Series V. The Influence of Growth Conditions Subsequent to Germination upon the Development of Bunt

In order to determine whether growth conditions after germination influence the amount of bunt in the resultant crop, as has proved to be the case with the covered smut of barley (**4**), an experiment was carried out in which each of two varieties of winter wheat, inoculated with spores of the New York collections of *T. laevis* and *T. Tritici,* were germinated in the temperature tanks in a good potting soil with a pH reaction of 7 and a moisture content of 61.9 per cent of the moisture holding capacity. The seedlings of each lot were then divided at random, one half being planted in the field, the other half in the greenhouse. Those plants matured in the field passed through the winter freezing conditions as do all fall sown grains in this climate, while the plants matured in the greenhouse made uninterrupted growth from germination until

maturity. This series was germinated at the varied temperatures, simultaneously with series II. The results are given in Table V.

TABLE V

THE INFLUENCE OF GROWTH CONDITIONS SUBSEQUENT TO GERMINATION OF WINTER WHEAT UPON THE DEVELOPMENT OF *Tilletia laevis* AND *Tilletia Tritici*

Variety	Matured in	*Tilletia Tritici*				*Tilletia laevis*			
		Number plants	Number smutted	Number partially smutted	Per cent infected	Number plants	Number smutted	Number partially smutted	Per cent infected
Dawson	Field	47	1	0	2.1	52	30	15	86.5
	Greenhouse	53	3	0	5.6	48	26	2	58.3
O. A. C. No. 104	Field	51	0	2	3.9	52	32	4	69.2
	Greenhouse	61	1	1	3.2	45	32	1	73.3

In so far as these data go there is no evidence that the growth of the host after the germination stages has a marked effect upon the development of bunt in these varieties of winter wheat. When this experiment was begun it seemed that the difficulties of securing infection in field plantings of spring wheat, which some authors have reported (**5**), might be due to some such factor as the rate of growth, since spring wheat is usually planted at a time when soil moistures and temperatures are well within the ranges for high infection (see Tables I and IV). Contrary to expectations, no wide differences are indicated by the results of this series of experiments. No generalization can be reached, however, until experiments dealing directly with spring wheat, under growth conditions comparable to those where infection difficulties have been experienced, have been carried out.

Series VI. The Influence of Rate of Germination upon the Percentage of Bunt

In recent papers Woolman and Humphrey (**22**) and Reed (**14**) have reviewed the literature upon the relation of infection to the varietal characters of prompt germination and growth. It is suf-

ficient here to point out that a number of workers have maintained that resistance is dependent upon quick germination and growth, while others have expressed great doubt that this is the case.

Reed and Faris (**16**) have recently brought forth data to show that resistance and susceptibility in the case of two sorghum smuts and the covered smut of oats are not correlated to the quickness with which the respective varieties emerge from the soil. Since some seedlings of a given variety emerged from the soil much earlier than did others when all were grown under the same conditions in our temperature tanks, the problem of determining whether a larger or smaller percentage of these early seedlings are infected, than of those which come up later, presented itself.

The remarkable uniformity with which the seedlings of barley emerge from the soil made such an experiment with that host very difficult. On the other hand the seedlings of the Dawson and O. A. C. No. 104 wheat varieties used in series I required five or six days from the time the first shoots began to emerge until all the plants had come up. This seemed suitable material for determining the above point.

The seed was inoculated and planted in a potting soil in the temperature tank as in series I. All seeds were planted a uniform depth of one inch. The seedlings which had emerged the first three days after the plants began to come up were marked with a paper ring and when transplanted these more advanced seedlings were put at one end of the row and the slower ones at the other. In one experiment the seeds were germinated at 5° C. and transplanted to the field and in a second experiment the seeds were germinated at a temperature varied from 14° C. to 10° C., after which one half of the faster and slower germinators of each set were planted in the greenhouse, the other half in the field. The results are given in Table VI.

Results with Tilletia laevis.—In every experiment of this series where either of the wheat varieties was inoculated with *T. laevis* those seedlings which emerged from the soil first were more heavily infected than those which came up later. In the variety Dawson, 84.7 per cent of the plants which came up first were infected while only 47.6 per cent of those which emerged later were

TABLE VI

THE INFLUENCE OF THE RATE OF GERMINATION UPON THE PERCENTAGE OF SMUT

Variety	Germination temperature ° C.	Matured in	Germination soil moisture	*Tilletia Tritici*						*Tilletia laevis*					
				Late seedlings			Early seedlings			Late seedlings			Early seedlings		
				Number plants	Number infected	Per cent infected	Number plants	Number infected	Per cent infected	Number plants	Number infected	Per cent infected	Number plants	Number infected	Per cent infected
Dawson	5	Field	60	10	0	0	35	6	17.1	23	14	60.9	30	23	76.7
	14–10	"	30	18	1	5.6	32	3	9.4	22	9	40.9	27	21	77.8
	"	"	60	26	0	0	21	1	4.8	16	10	62.5	36	35	97.2
	"	Greenhouse	60	22	0	0	31	3	9.6	23	7	30.4	25	21	84.0
		Total		76	1	1.3	119	13	10.9	84	40	47.6	118	100	84.7
O. A. C. No. 104	5	Field	60	23	0	0	23	1	4.3	19	7	36.8	23	20	86.9
	14–10	"	30	18	0	0	34	1	2.9	29	21	72.4	17	16	94.1
	"	"	60	23	1	4.3	28	1	3.6	27	12	44.4	25	24	96.0
	"	Greenhouse	60	26	1	3.9	35	1	2.9	20	8	40.0	25	25	100.0
		Total		90	2	2.2	120	4	3.3	95	48	50.5	90	85	94.4
Grand total—both varieties				166	3	1.8	239	17	7.1	179	88	49.2	208	185	88.9

diseased, a difference of 37.1 per cent. The O. A. C. No. 104 variety gave 50.5 per cent infection in the plants which emerged last while the earlier ones were smutted to the extent of 94.4 per cent, a difference of 43.9 per cent. With two varieties of wheat, germinated under controlled conditions at two soil temperatures, at two soil moistures, and when matured in both greenhouse and field a grand total of 185 plants out of the 208 which emerged first or 88.9 per cent were diseased, while only 88 of the 179 which came up later or 49.2 per cent were diseased. A total of eight comparative experiments with this smut gave higher percentages of infection in every case in the plants which emerged from the soil first.

Results with Tilletia Tritici.—As has been the case in all other experiments where this particular collection of *T. Tritici* was used, the percentages of infection here are very low. With two exceptions, however, the plants which emerged from the soil first were the most severely infected. In the two cases where the percentages are higher in the later seedlings, the number of plants infected is the same in both the earlier and later plants but the percentages are slightly higher in the latter because of the lower total number of plants.

The totals with each variety and the grand totals of both varieties show decidedly more infection in the seedlings which were quicker to emerge from the soil.

Series VII. The Influence of the Source of the Spores upon the Production of Bunt in Winter Wheat

In a recent paper Reed (**14**) has called attention to the different results secured by various investigators working in widely separated localities, with the same wheat variety and the same fungus species. He suggested the probability that the discrepancies recorded by the different observers may in part be explained upon the basis of specialized races in the species of *Tilletia.*

In light of the finding of biologic forms in the covered smut of barley by the writer (**3, 4**), and the discovery of specialized races in the oat smuts by Reed (**13**), as well as the suggestive nature of the above mentioned discrepancies, a limited series of experiments

was carried out to determine whether collections of either of the bunt fungi from widely separated localities would show well defined biologic forms.

Owing to a limited amount of seed, and, in some cases, a small quantity of smutted wheat, only ten varieties of wheat were grown. Twelve collections of smut, six of *Tilletia laevis* and six of *Tilletia Tritici,* were used. In addition to securing a preliminary test with these smut collections, it was hoped that sufficient smutted plants would occur to give inoculum for a much larger number of varieties the following year.

The results of this preliminary test are being given at this time because of the interesting results secured with some of the collections.

All seed was treated with hot water (presoaked 8 hours and then immersed in water at 54° C. for 13 minutes) and after thoroughly dry it was heavily inoculated with spores of the respective fungous collections, all of which had been made the season of 1923 except collection No. V of the *Tilletia laevis* and No. VI of *T. Tritici* which were gathered in 1922.[2]

All varieties were planted in the experiment field October 9th in 5 foot rows. The soil temperature during the period of germination ranged from 8° C. to 17° C. with an average of about 14° C. The soil was rather dry the first three days after planting but was then thoroughly soaked by a heavy rain which was followed by clear dry weather. The infection results are recorded in Tables VII and VIII.

Results with Tilletia laevis.—There are some differences in the amount of infection secured when spores from the various sources were used. Dawson wheat with collection V, Leap Prolific with collection IV and Club with collection III all gave much lower infections than were secured when the same varieties were inoculated with spores from other sources. Furthermore, the smut spores in all collections were viable as is evidenced by the high infections

[2] I am indebted to Dr. G. M. Reed, Curator, Brooklyn Botanic Garden, for supplying me with all smut collections except Nos. II and IV of *Tilletia laevis* and IV and V of *T. Tritici,* and for the seed of Kanred, Club, Red Rock, Poole, Mealy, Leap Prolific, and Fulcaster, and to Prof. H. H. Love of Cornell University for the other three varieties of wheat.

secured on some of the varieties with spores from each collection. It is quite likely that in an experiment with more varieties some would differentiate more sharply between these smut collections.

TABLE VII

THE PERCENTAGES OF INFECTION OF TEN WINTER WHEAT VARIETIES BY SIX COLLECTIONS OF *Tilletia laevis* KÜHN

Wheat variety	*Tilletia laevis* collection											
	No. I		No. II		No. III		No. IV		No. V		No. VI	
	Number plants	Per cent infected	Number plants	Per cent infected	Number plants	Per cent infected	Number plants	Per cent infected	Number plants	Per cent infected	Number plants	Per cent infected
Dawson (Honor)	51	49.2	54	70.4	48	54.2	49	67.3	45	17.1	48	75.0
Fulcaster	74	75.7	72	77.8	66	59.1	63	71.4	63	69.9	89	76.4
Junior No. 6	55	50.9	54	55.6	54	27.8	56	44.6	56	41.1	80	62.5
Leap Prolific	17	41.2	17	64.7	15	53.3	17	17.6	16	62.5	26	61.5
Mealy	95	74.7	122	69.7	122	64.8	97	72.2	102	64.7	81	87.6
O. A. C. No. 104	48	60.4	47	72.3	49	47.8	44	77.3	49	57.1	38	68.4
Poole	87	49.4	70	72.8	88	50.0	84	82.1	70	52.9	83	74.7
Red Rock	51	39.2	22	72.7	33	27.3	28	32.1	27	51.9	66	51.5
Club	66	33.3	57	24.6	63	9.5	50	28.0	56	25.0	35	37.1
Kanred	38	39.5	—	—	—	—	36	50.0	—	—	—	—

TABLE VIII

THE PERCENTAGES OF INFECTION OF TEN WINTER WHEAT VARIETIES BY SIX COLLECTIONS OF *Tilletia Tritici* (BJERK.) WINTER

Wheat variety	*Tilletia Tritici* collection											
	No. I		No. II		No. III		No. IV		No. V		No. VI	
	Number plants	Per cent infected	Number plants	Per cent infected	Number plants	Per cent infected	Number plants	Per cent infected	Number plants	Per cent infected	Number plants	Per cent infected
Dawson (Honor)	49	71.4	41	75.6	56	75.0	43	13.9	44	0	48	37.5
Fulcaster	71	90.1	62	79.0	63	73.0	66	6.0	64	4.7	67	56.9
Junior No. 6	59	66.1	65	78.5	51	52.9	67	0.0	66	0.0	65	27.7
Leap Prolific	14	71.4	19	68.4	25	64.0	25	4.0	32	0.0	22	45.4
Mealy	116	68.1	93	87.1	82	54.9	84	0.0	75	0.0	104	88.5
O. A. C. No. 104	46	80.4	38	76.3	47	68.1	57	5.3	42	0.0	46	63.0
Poole	67	76.1	68	75.0	56	76.8	54	1.9	62	1.6	79	72.2
Red Rock	14	78.6	15	66.7	25	80.0	38	0.0	33	0.0	33	30.3
Club	58	29.3	43	69.8	70	52.9	61	4.9	86	3.4	51	1.8
Kanred	36	38.8	36	86.1	43	76.7	38	0.0	39	0.0	34	0.0

The present data are suggestive but further work is necessary before the true nature of these differences can be ascertained.

Results with Tilletia Tritici.—Very satisfactory infections were secured with collections I, II, III and VI of this species. The high infections secured with some variety with each of these four collections of spores make it quite certain that any infection differences shown by them are not due to a lack of viable spores. With collections IV and V, however, this is not the case and failure to get high infection in any variety may mean that for some reason the spores had lost their ability to infect any host. These two collections were made in the summer of 1923 at the same time the New York *Tilletia Tritici* used in the experiments of series I and II was collected. My entire season's results with these collections have been unsatisfactory. Care has been taken to preserve smutted heads for further study to learn whether this lack of satisfactory infections is due to some storage condition, or whether the wheat varieties used are resistant to these two smut collections.

Very interesting indeed are the infections secured with Club and Kanred wheats when inoculated with spores of the first three collections as compared with the amount of disease obtained when the spores of collection VI were used as inoculum. The spores of the latter collection were viable as is evidenced by the fact that the variety Mealy gave 88.5 per cent infection. Therefore, it would seem that the small percentage of diseased plants of Club wheat, and complete lack of infection in Kanred, are due to a certain amount of resistance on the part of these two varieties to this particular smut collection. In light of the results secured in the temperature and moisture experiments, there seems to be no reason to believe that this lack of infection is due to any sharp environal factor. Furthermore, high infections were secured with other varieties on both sides of these rows. On the other hand, both Club and Kanred were very susceptible to collections I, II and III. The Club wheat gave 29.3, 69.8 and 52.9 and Kanred gave 38.8, 86.1 and 76.7 per cents of infection with those three respective smut collections. There seems little reason to doubt that we are here dealing with specific differences in the ability of the spores in these collections to infect these two varieties. These data, while

not exhaustive, are clear cut and in light of the infection percentages secured by Stephens and Woolman (**18**) at Moro and Corvallis, Oregon, which indicate that Kanred is resistant to *Tilletia Tritici*, it seems quite likely that these results are representative of what would happen in more extensive experiments.

DISCUSSION AND CONCLUSIONS

SOIL FACTORS INFLUENCING INFECTION

The soil temperature during the period of germination has proven to be the most important factor in the infection of Dawson and O. A. C. No. 104 winter wheat by *Tilletia laevis*. The character of the substrata and the percentage of moisture in both soil and sand did not closely limit the amount of infections secured in series II. The importance of low soil temperatures during germination is further demonstrated in the tank experiments recorded in Table IV, in which a winter variety and two varieties of spring wheat were germinated in the spring in controlled temperature tanks and matured in the experiment field. In this series of experiments 5° C. proved most favorable for the development of *T. laevis* in Dawson and Red Fife, but 10° C. was more favorable for the development of both *T. Tritici* and *T. laevis* in the variety Marquis.

In two sorghum Kernel smuts Reed and Faris (**15**) report similar results in that they secured the highest infection in Kaoliang with both *Sphacelotheca Sorghi* and *S. cruenta* and Darso with *S. cruenta* (the only one to which it is susceptible) at 20° C., while Kafir and Sorgo gave higher infections with both smuts at 25° C. than at 20° C. Dickson (**1**) found that the temperatures most favorable for high infections by the seedling blight fungus (*Gibberella Saubinetii*) of wheat and corn were different for these two host plants. From his results with this organism he concludes that "the influence of the environmental factors on the hosts seems to be the fundamental cause of susceptibility to the disease."

Upon first thought a logical conclusion from our results with sorghum and those with wheat seemed to be that the temperature

was influencing the host since the two species of the respective parasites gave the highest infection at the same temperature when a particular host variety was used, but this temperature for maximum infection was different for the two varieties in each case. However, it seems quite as reasonable to conclude that we have these different points for highest infections in both sorghum and wheat because the varieties are different from the start. That is, it is not necessary to suppose that the treatments rendered the varieties more susceptible at these different temperatures for they may have had this inherent difference to begin with.

I have shown in the covered smut of barley that the point for highest infection may be varied by using soils of different pH reactions, if other factors are kept the same. Reed and Faris (**16**) found that the optimum temperature for infection in the covered smut of oats could be changed by using different soil moisture contents, other factors being the same. In the above experiments the optimum temperature for infection is varied by using a different variety, all other conditions being the same. Therefore, the optimum soil temperature, moisture and acidity are not fixed, but must be considered in relation to each other; and now we must add in relation to the response of the variety to the interaction of all these, and perhaps other environmental influences.

It is significant to find that the relative susceptibility of two wheat varieties to bunt may be quite different when each is exposed at different temperatures to the same combination of other environal influences. It may well be that some of the fluctuations in infection percentages secured by planting several varieties upon the same date, at various intervals during the season, are due to these different varietal responses to the same combination of conditions, rather than to very localized differences of soil conditions.

The results with *T. Tritici* also indicate that the low germination temperatures are more favorable for high infection. The plants germinated in the 10° C. tanks were more heavily infected in the two varieties planted in the fall, and in the two spring varieties, but the Dawson sown in the spring had a slightly higher percentage of the plants germinated in the 5° C. tank bunted. Both species of these fungi, therefore, find conditions most favor-

able for infection at low soil temperatures, and both seem to have about the same temperature range. A few partially smutted plants were produced in experiments where the seed inoculated with *T. laevis* was germinated at 25° and 30° C. (see Tables I and IV), however, while no smutted plants were secured with the *T. Tritici* at these higher temperatures.

The date of planting experiments give no marked differences in the percentages of infection secured when the varieties were seeded October 9th or 25th. This is the result which would be expected since the soil temperatures during the period of germination were low and hence within the range where fairly constant results may be expected (see Figs. 1 and 4).

PHYSIOLOGICAL FACTORS INFLUENCING INFECTION

Neither the results of the experiments upon the environmental factors nor those upon the influence of growth conditions after the period of infection throw much light upon the reason why it is difficult to secure satisfactory infection in spring wheat as recorded by some authors (**5**). The possibility that wider extremes of one or more of these factors may explain this situation should not be overlooked.

The results of the experiments upon the rate of germination of seeds within the variety indicate that the more vigorous seedlings are more subject to infection. In this respect bunt of wheat is like the rusts as reported by Stakman (**17**) and Raines (**11, 12**), who find that whatever is conducive to the vigorous development of the host is usually conducive to the vigorous development of the parasite, and hence, unlike the seedling blight organism (*Gibberella Saubinetii* (Mont.) Sacc.) of wheat and corn, as reported by Dickson, Eckerson, and Link (**2**) who find "that conditions of environment, which are unfavorable for the best development of the cereal seedling, predispose it to attack by the fungus."

There is considerable evidence that we have a fundamental difference between those fungi, which are strictly parasitic, such as the smuts and rusts, and those which are semi-saprophytic, as is *Gibberella Saubinetii,* in that the former group requires vigorously growing host plants for its best development, while the latter class

finds conditions more favorable when the host plant is somewhat weakened.

The evidence presented in Tables VII and VIII, which indicates that different collections of both *T. laevis* and *T. Tritici* may give quite different percentages of infection when seed lots of a variety are inoculated with spores of the various collections and grown under comparable conditions, indicates that these bunt species are specialized into races, as suggested by Reed (**14**).

The scientific and economic importance of wheat bunt justifies a much more complete study of the infection capabilities of a large number of spore collections upon a considerable number of wheat varieties. It is no longer sufficient to assume that results secured with one spore collection represent what would happen were other collections of the same bunt species used.

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NOTES AND BRIEF ARTICLES

Professor Bruce Fink is spending his sabbatical leave at the New York Botanical Garden and other botanical centers looking over lichens preparatory to a monograph of that group of plants for the United States.

Mr. L. E. Wehmeyer of the University of Michigan spent a few days at the New York Botanical Garden looking over some of the fungi belonging to the family Valsaceae. He is especially interested in connecting these forms of ascomycetous fungi with their pycnidial stages.

"Mushrooms, Edible and Otherwise" is the title of a splendidly illustrated article by L. W. Brownell in the September number of *Nature Magazine*.

W. H. Long refers to *Cenangium Abietis* as one of the useful factors in bringing about self pruning of the western yellow pine, this pruning being essential to the production of clear lumber.

An extensive illustrated article appears in the June number of American Journal of Botany on the *Helminthosporium* disease of rice in the southern United States and the Philippine Islands, caused by *Helminthosporium Oryzae*.

In his "Revisión de las Meliolas Argentinas" C. Spegazzini (Anal. Mus. Hist. Nat. Buenos Aires **32**: 339–393. 1924) records a number of new species of *Meliola* together with critical descriptions of those previously known from Argentine.

We learn from *Science* that Professor and Mrs. F. L. Stevens of the University of Illinois have left for a six months collecting

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trip in South America. They expect to visit Panama, Ecuador, Peru, Bolivia, Chile, Argentine and Brazil, returning in February.

In *Phytopathology* for July, J. C. Walker reports the occurrence of white rot of onion in America caused by *Sclerotium cepivorum* Berk. G. B. Ramsey in the same number describes *Sclerotinia intermedia* n. sp. as the causal organism in the decay of salsify and carrots.

We are informed through *Science* that Mr. J. F. Rock, head of the National Geographic Society's expedition into southwestern Szechuan and southeastern Tibet, has just returned with a large collection of plants including a blight resistant chestnut tree. His collection of chestnuts include several species unknown to the horticultural world and possibly new to science.

Mushroom collectors are often puzzled by species of *Lactaria* parasitized with *Hypomyces Lactifluorum* which obliterates the gills and gives the entire host an orange color. Large specimens have recently been sent in for determination, the collector apparently not recognizing this phenomenon as a " fungus on a fungus."

Miss Anna E. Jenkins of the Department of Agriculture, Washington, spent a day at the New York Botanical Garden looking over the collections of Exoascales. Miss Jenkins is making a critical study of this order of parasitic fungi preparatory to a monograph of the species and would doubtless be glad to see fresh material from anyone caring to send it in. She also made a survey of the rose garden with special reference to brown rot, *Diaporthe umbrina*, a fungus which seems to be causing a great deal of damage to cultivated roses.

Under the title " Algunos Honguitos Portoriqueños " C. Spegazzini (Bol. Acad. Ci. Córdoba **26:** 335–368. 1923) describes the following genera: *Meliolidium* n. gen. based on *Meliolidium*

portoricense n. sp.; *Stevensula* n. gen. on *Stevensula monensis* n. sp.; *Lembosidium* n. gen. on *Lembosidium portoricense* n. sp.; *Melioliphila* n. gen. on *Calonectria graminicola* Stev.; *Amphinectria* n. gen. on *Amphinectria portoricensis* n. sp.; *Subiculicola* n. gen. on *Calonectria ambigua* Speg.; *Micropiltidium* n. gen. on *Micropeltidium monense* n. sp.; *Scolecopeltella* n. gen. on *Scolecopeltella microcarpa* n. sp.; and *Monospermella* n. gen. on *Monospermella portoricensis* n. sp. Also the following species not included above: *Trichomerium portoricense* n. sp.; *Morenoella portoricensis* n. sp.; *Micropeltidium portoricense* n. sp.; *Scolecopeltis portoricensis* n. sp.; *Scolecopeltis pachyasca* n. sp.; *Scolecopeltella portoricensis* n. sp.; *Puiggarina Ichnanthi* n. sp.; *Phyllachora orbicularis* n. sp.; *Dothidella andiricola* n. sp. A number of new forms were also described. Eight text figures are used in illustrating the species and genera described.

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